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HEALTHCARE PROFESSIONALS' ONLINE QUERIES IN DETECTION OF INFECTIOUS DISEASE EPIDEMICS

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DOCTORAL DISSERTATION

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ABSTRACT

The aim of this study was to analyze online information seeking by healthcare professionals (HCPs) in order to both evaluate its extent and assess whether it can be used in clinically relevant settings, such as epidemiology.

HCPs need reliable medical information to be used in daily clinical work. Physician's Databases (PD) serve as online medical sources that are available throughout the Finnish healthcare system and provide medical information for HCPs performing the searches. Every query is included in the log files of PD.

To analyze information needs among various HCPs, the queries in different healthcare sectors (primary care, specialized care, pharmacies, and private care) showed the known characteristics of each sector in terms of the time of day, weekdays, weekends, seasons, and quantities of HCPs working in a specific healthcare sector nationwide. To detect infectious disease epidemics, similar patterns were found between the diagnoses and queries of Lyme borreliosis (LB) performed by both HCPs and the general public. The media publications on LB only occasionally related to queries. HCPs' queries on oseltamivir and influenza showed similar patterns annually compared with the diagnoses and laboratory reports on influenza. When detecting influenza epidemics, the queries on oseltamivir preceded influenza diagnoses by -0.80 weeks (95% CI: -1.0, 0.0, $p = 0.000$) with high correlation ($\tau = 0.943$); and the queries on influenza preceded oseltamivir queries by -0.80 weeks (95% CI: -1.2, 0.0, $p = 0.015$) with high correlation ($\tau = 0.738$) and influenza diagnoses by -1.60 weeks (95% CI: -1.8, -1.0, $p = 0.000$) with high correlation ($\tau = 0.894$).

Assessing the log files of PD, and comparing them with epidemiological registers on infectious diseases, heralds a new approach for using HCPs' online queries from real-time databases as an additional source of information for disease surveillance when detecting epidemics.

TIIVISTELMÄ

Väitöskirjan tavoitteena oli tutkia terveydenhuollon ammattilaisten tiedonhakua ja sen yhteyttä infektioepidemioihin. Duodecimin Terveysportin Lääkärin tietokannat on internetpohjainen tietolähde terveydenhuollon ammattilaisille, jotka hakevat luotettavaa lääketieteellistä tietoa potilaiden hoitoon. Jokainen haku tallentuu tietokannan lokitietoihin. Tutkimuksen tarkoituksena oli arvioida sekä tiedonhaun laajuutta että sen hyödynnettävyyttä esimerkiksi infektioepidemiologiassa.

Tutkimuksessa (1) arvioitiin terveydenhuollon ammattilaisten tiedontarvetta tutkimalla eri terveydenhuollon sektoreilla (perusterveydenhuolto, erikoissairaanhoito, apteekit ja yksityissektori) tapahtuvaa tiedonhakua Lääkärin tietokannoista. Niin haun vuorokaudenajan, viikonpäivän, vuodenajan kuin sektorilla työskentelevien ammattilaisten määrän todettiin olevan ominaisia kullekin sektorille. Tämän jälkeen (2) verrattiin Lääkärin tietokantojen Lymen borrelioosi -hakuja ja Terveyden ja hyvinvoinnin laitoksen rekisterin borrelioosidiagnooseja toisiinsa. Niillä havaittiin ajallinen yhteys: haut ja diagnoosit ilmenevät samaan aikaan. Tämä tarkoittaa, että ammattilaisten hakuja voitaisiin hyödyntää epidemioiden seurannassa perinteisten rekistereiden rinnalla. Tutkimuksessa myös (3) verrattiin ammattilaisten Lääkärin tietokantojen Lymen borrelioosi -hakuja ja maallikoiden Terveyskirjaston Lymen borrelioosi -hakuja toisiinsa. Niissäkin toteutui samanlainen ajallinen yhteys, joka noudatti perinteistä infektioepidemiologista rekisteriä borrelioosista. Suurimpien suomalaisten medioiden verkkosivuilta kerättiin borrelioosiin liittyvät mediajulkaisut, ja ne olivat yhteydessä Terveyskirjaston Lymen borrelioosi -hakuihin vain ajoittain. Borrelioosin medianäkyvyys saattaa kuitenkin vaikuttaa sekä ammattilaisten että maallikoiden internetin tiedonhakuun. Lopuksi (4) tutkittiin terveydenhuollon ammattilaisten Lääkärin tietokantojen influenssahakuja ja Duodecimin lääketietokannan oseltamiviirihakuja. Niillä todettiin yhteys Terveyden ja hyvinvoinnin laitoksen influenssadiagnooseihin ja laboratoriolöydöksiin. Tämä tarkoittaa, että kun oseltamiviirihaut edelsivät ajallisesti influenssadiagnooseja ja kun influenssahaut edelsivät sekä oseltamiviirihakuja että influenssadiagnooseja, niin ammattilaisten hakuja tietokannasta voitaisiin hyödyntää influenssaepidemioiden seurannassa.

Lokitietojen vertaaminen infektioepidemiologisiin rekistereihin tuo uutta tietoa terveydenhuollon ammattilaisten internetin tiedonhausta. Hakutietoa on mahdollista hyödyntää perinteisten rekistereiden rinnalla infektiotautien ennakoinnissa ja seurannassa.

CONTENTS

LIST OF THE ORIGINAL PUBLICATIONS

The doctoral thesis is based on the following original publications listed by Roman numerals I–IV and referred to as studies I–IV in the text.

I Pesälä S, Mustonen P, Kaila M, Helve O. Evidence needs among health professionals – Online medical queries in different health sectors in Finland: A log file analysis (submitted to PLOS ONE, January 17, 2020).

II Pesälä S, Virtanen MJ, Sane J, Jousimaa J, Lyytikäinen O, Murtopuro S, Mustonen P, Kaila M, Helve O. Health care professionals' evidence-based medicine internet searches closely mimic the known seasonal variation of Lyme borreliosis: a register-based study. JMIR Public Health Surveill. 2017 Apr 11;3(2):e19.

III Pesälä S, Virtanen MJ, Sane J, Mustonen P, Kaila M, Helve O. Health information-seeking patterns of the general public and indications for disease surveillance: register-based study using Lyme disease. JMIR Public Health Surveill. 2017 Nov 6;3(4):e86.

IV Pesälä S, Virtanen MJ, Mukka M, Ylilammi K, Mustonen P, Kaila M, Helve O. Healthcare professionals' queries on oseltamivir and influenza in Finland 2011-2016—Can we detect influenza epidemics with specific online searches? Influenza Other Respir Viruses. 2019 Jul;13(4):364-371.

 Some unpublished data is also presented in this thesis.

ABBREVIATIONS

ARGO	AutoRegression with Google search data
Avohilmo	Register of public primary healthcare diagnoses
CINAHL	Cumulative Index to Nursing and Allied Health Literature
EBM	Evidence-based medicine
ECDC	European Centres for Disease Prevention and Control
GFT	Google Flu Trends
HCPs	Healthcare professionals
HL	Health Library (Terveyskirjasto in Finnish)
ICD-10	International Classification of Diseases, 10th Revision
ICPC-2	International Classification of Primary Care, 2nd Edition
LB	Lyme borreliosis
MEM	Moving epidemic method
MeSH	Medical Subject Heading
NIDR	National Infectious Diseases Register
NIHW	National Institute for Health and Welfare
PD	Physician's Databases (Lääkärin tietokannat in Finnish)
SARIMA	Seasonal autoregressive moving average model
WHO	World Health Organization

TERMS

Medical information	Organized medical data to reduce uncertainty, take decisions, and guide actions. Can be found from various sources, such as textbooks or online (Wyatt and Liu, 2002).
Medical knowledge	A healthcare professional's personal knowledge on medical information with its interpretation and broader understanding on the subject in order to make clinical decisions based on best medical evidence (Wyatt and Liu, 2002; Kolars et al., 2003).
Medical evidence	Best scientific knowledge available in medicine (Cochrane Library; Gray, 2001).
Evidence (or information) needs	A healthcare professional lacks medical knowledge, which triggers information seeking from given sources (textbooks, online) in order to find reliable medical information to be used in clinical work (Allison et al., 1999; Clarke et al., 2013).
Infodemiology (information epidemiology)	Epidemiological data and online health-information are combined, and information is used in an electronic medium or in a population aiming at informing public health and public policy (Eysenbach, 2009).
Infoveillance (information surveillance)	Infodemiology data is used for surveillance purposes (Eysenbach, 2009).

1 INTRODUCTION

Healthcare professionals (HCPs) need medical information in clinical work. Diagnoses, medication, and treatment are the most queried topics from the sources (Clarke et al., 2013). Several obstacles may disturb information retrieval and its usability, such as unreliable sources, quality of information, and searching skills (Dawes and Sampson, 2003). The use of online medical databases (Pubmed, the Cochrane Library, and Cumulative Index to Nursing and Allied Health Literature [CINAHL]) has increased over time among HCPs (Clarke et al., 2013; Kannampallil et al., 2013; Weng et al., 2013). However, HCPs may use unreliable information sources (Google) providing heterogeneous health-related information (Purcell et al., 2002; Diaz et al., 2002; Eysenbach et al., 2002). Many sources still fail to characterize the users performing the searches.

In Finland, Physician's Databases (PD) serve as online medical sources aimed at HCPs, comprising physicians, nurses, and pharmacists. Evidence needs among HCPs working in different healthcare sectors may vary (Hider et al., 2009; Cook et al., 2017). The healthcare sectors in Finland (primary care, specialized care, pharmacies, and private care) have their own distinct features.

Infectious diseases, Lyme borreliosis (LB) and influenza, show seasonal incidences in epidemiological registers: LB in the summer and influenza in the winter (Mölläri and Saukkonen, 2017; Infectious Diseases in Finland 2017). HCPs search for information from the databases during epidemics. These two infectious diseases were chosen as case studies to be analyzed in their distinct seasonal variations, and comparisons could be made with PD log data. Epidemiological data and online health-information could be combined in order to enhance disease surveillance (Eysenbach, 2009).

Using the dedicated medical databases, how HCPs seek information, in sectors and queries on seasonal infectious diseases, needs to be characterized. This study describes: (1) HCPs' evidence needs in different sectors; and (2) HCPs' queries in comparison to traditional register-data on infectious diseases whether the queries could be used in disease surveillance when detecting epidemics.

2 REVIEW OF THE LITERATURE

2.1 LITERATURE SEARCH

HCPs use different sources of medical information in clinical work. Although online sources have been increasingly used over time, many obstacles may still exist when retrieving information, such as unreliable sources, quality of information, and lack of time and searching skills. Various HCPs have different information needs depending on the healthcare sectors that they work in. To characterize the articles that have been published on HCPs' information seeking and the related effect on practice, a literature search was performed.

The aim of the literature search was: (1) to assess medical information seeking from online sources among physicians, nurses, and pharmacists; and (2) to describe its effect on clinical decisions and practice. The following Medical Subject Heading (MeSH) terms were used: "*information seeking behavior", "health knowledge, attitudes, practice", "evidence-based practice", "health personnel",* and *"medical informatics"*. The MeSH terms were combined with the following terms: *health care professional**, *information search**, *information seek**, *information quer**, *evidence need**, and *medical knowledge**. The MeSH term *"medical informatics"* was combined with all the previous terms in order to find the studies related to computer or online databases. The Pubmed search was carried out for content published between 1983 and April 11, 2019.

A total of 215 studies were found from Pubmed concerning the terms outlined above. The inclusion and exclusion criteria were set in order to meet the aim of the literature search. The studies must include: (1) clinical physicians, nurses, or pharmacists who use; (2) computer or online databases; (3) in primary or specialized care, or pharmacies. All research designs were included: (systematic) reviews; original articles; quantitative or qualitative studies; or pilot projects. The studies must be in English. No time limits for the studies were set. The studies concerning healthcare students' information seeking were excluded. When following the inclusion and exclusion criteria, a total of 27 studies were finally selected. Altogether 21 studies on physicians included 4 studies reporting on primary-care physicians and 14 studies on specialized-care physicians. Three studies could not distinguish primary- and specialized-care physicians. The 8 studies on nurses were comprised of 1 study on primary-care nurses and 7 included specialized-care nurses. Five studies included pharmacists. The selected studies are shown in the following tables (Tables 1A, 1B, and 1C). Although the inclusion criteria contained electronic or online databases, the selected studies may also have included traditional sources (books, colleagues) as the main source of information, thus listed in the study results. Many studies included various HCPs and sectors, thus the same study may be shown in multiple tables.

2.2 HEALTHCARE PROFESSIONALS' (HCPs') INFORMATION SEEKING

2.2.1 PHYSICIANS' INFORMATION SEEKING

The literature search found that physicians, nurses, and pharmacists search for medical information from various sources differently. Physicians working in primary care use traditional information sources, such as colleagues and books (Ely et al., 1992; Einarson et al., 2004; Clarke et al., 2013), although the use of online sources has increased over time (Einarson et al., 2004; Clarke et al., 2013; Weng et al., 2013). The main needs for clinical information among primary-care physicians are diagnoses, medication, and treatment (Clarke et al., 2013). In specialized care, hospital physicians mostly consult colleagues and medical textbooks over electronic sources when searching for information or making clinical decisions (Callen et al., 2008). However, online sources have increased in this sector over time (Weng et al., 2013). Therefore, they may be the most important sources of information among hospital physicians (Chisholm and Finnell, 2012; Kannampallil et al., 2013; Weng et al., 2013; Beck and Tieder, 2015; Adeponle et al., 2016). Information seeking among clinicians may vary due to different characteristics between hospital wards as well as between clinicians (Tan et al., 2006). Some physicians may only trust their own clinical experience when treating patients (Kahouei et al., 2015). In hospitals, physicians access online information sources (electronic databases, journals, and books) more often than other professionals (Weng et al., 2013). Using authoritative online information sources, hospital physicians find that these sources fulfill all types of their information needs and enhance medical practice competence (Mikalef et al., 2017). Google and UpToDate are the most utilized electronic sources among emergency department physicians and pediatric hospitalists (Chisholm and Finnell, 2012; Beck and Tieder, 2015). However, these online sources may raise concern in terms of the quality of information they provide. Education and training in using electronic sources and formulating clinical questions among hospital physicians may enhance attitude and skills towards computer systems, thus improving practice and patient care (Cheng, 2003; D'Alessandro et al., 2004; Shariff et al., 2012). Several factors may have an influence on hospital physicians' information searching from electronic databases, such as English language and computer skills (Callen et al., 2008), inadequate time (D'Alessandro et al., 2004; Adeponle et al., 2016), and age (Callen et al., 2008; Adeponle et al., 2016). When HCPs find answers to clinical questions, the use of interactive online algorithms may vary across search topics, specialties, and individual clinicians. Generalists use algorithms more often than specialists, while specialists search for topics within their own specialty. Thus, specialists may have unique needs for medical information (Cook et al., 2017). A wide variation in information seeking behavior among physicians exists (Dawes and Sampson, 2003; Weng et al., 2013). The studies on physicians' information seeking are shown in Table 1A.

In Finland, younger physicians often seek medical information from national written guidelines, while physicians with special competencies read original articles or reviews from international medical journals (Renko et al., 2016). Using information sources, medical

students and younger physicians prefer Finnish to English. Electronic databases (PD) are the most read sources of information among medical students (Renko et al., 2011). Lack of time is the most important problem when searching for information, but this eases over working years (Renko et al., 2013). Medical students spend an average of seven hours a week reading literature and medical sources, while younger physicians spend three hours a week (Renko et al., 2011; Renko et al., 2013).

Table 1A *Studies on physicians' information seeking in primary and specialized care, including the main information sources.*

Study name	**Authors (year, country)**	**Study results**	
		Main information sources	**Other results**
Primary care			
Information needs of generalists and specialists using online best-practice algorithms to answer clinical questions	Cook et al. (2017, USA)	online sources	generalists use algorithms more often than specialists the use of interactive online algorithms varies across topics, specialties, and individual clinicians
Information needs and information-seeking behaviour analysis of primary care physicians and nurses: a literature review	Clarke et al. (2013, USA)	colleagues	information needs among physicians relate to diagnoses, drugs, and treatment a rise in Internet usage is apparent
How physicians perceive and utilize information from a teratogen information service: the Motherisk Program	Einarson et al. (2004, Canada)	paper sources	minority of family physicians seek information from electronic sources
The information needs of family physicians: case-specific clinical questions	Ely et al. (1992, USA)	colleagues, books	drug-prescribing questions are the most common
Primary and specialized care			
Conventional and complementary cancer treatments: where do conventional and complementary providers seek information about these modalities?	Stub et al. (2018, Norway)	online sources	doctors search for information on conventional cancer treatment from EBM sources colleagues also remain an important source
Online information seeking behaviour by nurses and physicians: a cross-sectional study	Lialiou, Mantas (2016, Greece)	online sources	among physicians the main reason for using online databases is a knowledge gap they believe that the use of online databases improves patient care

Knowledge management in clinical practice: a systematic review of information seeking behavior in physicians	Dawes, Sampson (2003, Canada)	colleagues, text sources	wide variation in information seeking behavior exists among physicians several obstacles disturb information retrieval
Specialized care			
Online information search behaviour of physicians	Mikalef et al. (2017, Greece)	online sources	authoritative online information sources fulfill all types of information needs among physicians
Information needs of generalists and specialists using online best-practice algorithms to answer clinical questions	Cook et al. (2017, USA)	online sources	specialists may have unique information needs within their own specialty the use of interactive online algorithms varies across topics, specialties, and individual clinicians
The University of Manitoba Psychiatry Toolkit: development and evaluation	Adeponle et al. (2016, Canada)	colleagues	psychiatrists prefer colleagues when gathering health information, they may also use electronic sources lack of time and search skills are the main barriers
Electronic resources preferred by pediatric hospitalists for clinical care	Beck, Tieder (2015, USA)	online sources	quality of the sources may raise discussion (Google, UpToDate)
Strategy of health information seeking among physicians, medical residents, and students after introducing digital library and information technology in teaching hospitals of Iran	Kahouei et al. (2015, Iran)	physician's own clinical experience, online sources	a quarter of hospital physicians always use PubMed or MEDLINE in information seeking
Understanding the nature of information seeking behavior in critical care: implications for the design of health information technology	Kannampallil et al. (2013, USA)	electronic sources	sources reflect differences in the nature of knowledge utilization across resources (paper, electronic)
Information-searching behaviors of main and allied health professionals: a nationwide survey in Taiwan	Weng et al. (2013, Taiwan)	online sources	physicians access Internet professional databases more often than other professionals, the most common source is MEDLINE hospital health professionals use commonly Web portal for information searching, followed by colleague consultations information searching varies among different professionals

Increasing utilization of Internet-based resources following efforts to promote evidence-based medicine: a national study in Taiwan	Weng et al. (2013, Taiwan)	online sources	the use of Internet medical sources has increased among physicians during 2007–11 access to textbooks and printed journals has not changed during 2007–11 Internet is a prominent source of medical information for physicians
Impact of PubMed search filters on the retrieval of evidence by physicians	Shariff et al. (2012, Canada)	online sources	Pubmed search filters used by nephrologists, improve searches, thus may enhance patient care
Emergency department physician internet use during clinical encounters	Chisholm, Finnell (2012, USA)	online sources	drug information is the most searched topic lower-tier EBM sources are mostly used (Google, UpToDate)
Clinical information sources used by hospital doctors in Mongolia	Callen et al. (2008, Mongolia)	colleagues, textbooks	English language and computer skills are obstacles to electronic searches
Information sources used by New South Wales cancer clinicians: a qualitative study	Tan et al. (2006, Australia)	colleagues	information seeking among cancer clinicians varies between ward-to-ward and clinician-to-clinician in hospitals a quick answer or an unfamiliar clinical situation triggers clinicians to consult experienced colleagues unstandardized approach for information seeking on medications exists
An evaluation of information-seeking behaviors of general pediatricians	D'Alessandro et al. (2004, USA)	paper sources	general pediatricians with unanswered clinical questions use computer sources more after intervention
Educational workshop improved information-seeking skills, knowledge, attitudes and the search outcome of hospital clinicians: a randomised controlled trial	Cheng (2003, Hong Kong)	printed sources	hospital clinicians change their attitudes more positive towards the use of electronic information services after end-user training

2.2.2 NURSES' INFORMATION SEEKING

Nurses working in primary care need health information related to diagnoses, treatment, and medication (Clarke et al., 2013). Colleagues are the most important source of information, although the use of online sources has increased (Clarke et al., 2013; Stub et al., 2018). In specialized care, hospital nurses often consult colleagues, textbooks, or printed journals when needing information for clinical work (Tannery et al., 2007; Weng et al.,

2013). Education and access to knowledge-based electronic information sources could change information seeking behavior among nurses (Tannery et al., 2007). Pediatric nurses with greater computer and online seeking skills may benefit more from computer-based information (Secco et al., 2006). Nurses consider that the main source of information is online scientific-based knowledge and they may use more non-English information sources compared to physicians (Weng et al., 2013). Lack of time prevails as the main obstacle when searching for information (Argyri et al., 2014). Both physicians and nurses want to find EBM information that can be used in clinical practice (Mikalef et al., 2017; Stub et al., 2018) and a knowledge gap is the main reason for using online databases (Lialiou and Mantas, 2016). Nurses find that the quality and availability of information has an influence on nursing care (Argyri et al., 2014) and using online databases would improve patient care (Lialiou and Mantas, 2016). The studies on nurses' information seeking are shown in Table 1B.

Table 1B *Studies on nurses' information seeking in primary and specialized care, including the main information sources.*

Study name	**Authors (year, country)**	**Study results**	
		Main information sources	**Other results**
Primary care			
Information needs and information-seeking behaviour analysis of primary care physicians and nurses: a literature review	Clarke et al. (2013, USA)	colleagues	information needs among nurses relate to diagnoses, drugs, and treatment a rise in Internet usage is apparent
Specialized care			
Conventional and complementary cancer treatments: where do conventional and complementary providers seek information about these modalities?	Stub et al. (2018, Norway)	online sources	nurses search for information on conventional cancer treatment from EBM sources colleagues also remain an important source
Online information seeking behaviour by nurses and physicians: a cross-sectional study	Lialiou, Mantas (2016, Greece)	online sources	among nurses the main reason for using online databases is a knowledge gap they believe that the use of online databases improves patient care
A survey on information seeking behaviour of nurses at a private hospital in Greece	Argyri et al. (2014, Greece)	online sources	information quality and availability are considered to influence nursing care and practices
Information-searching behaviors of main and allied health professionals: a nationwide survey in Taiwan	Weng et al. (2013, Taiwan)	colleagues	nurses consult more colleagues comparing to other professionals and use more non-English sources
Increasing utilization of Internet-based resources following efforts to promote evidence-based medicine: a national study in Taiwan	Weng et al. (2013, Taiwan)	online sources	the use of Internet medical sources has increased among nurses during 2007–11 access to textbooks and printed journals has not changed during 2007–11

			Internet is a prominent source of medical information for nurses
Hospital nurses' use of knowledge-based information resources	Tannery et al. (2007, USA)	electronic sources	rural hospital nurses' use of health library's electronic sources increases after providing access to library sources
A survey study of pediatric nurses' use of information sources	Secco et al. (2006, Canada)	online and electronic sources	bedside pediatric nurses with greater computer and online searching skills use more computer-based information

2.2.3 PHARMACISTS' INFORMATION SEEKING

Pharmacists working in community pharmacies or hospitals use electronic or online sources when searching for information related to patients' medication (Weng et al., 2013; Wallace et al., 2014). Safety issues (such as drug-to-drug interactions [Robertson et al., 2010; Beeler et al., 2013]), electronic prescribing (Warholak et al., 2011), and clinical-decision support systems (Robertson et al., 2010) are the areas that pharmacists find the most important in the field of electronic information platforms. They may adjust medication according to the instructions based on UpToDate recommendations (Wallace et al., 2014) and use online pharmaceutical databases when searching for information on medication in hospitals (Weng et al., 2013). A drug-to-drug interaction checker can be used between pharmacists and physicians in hospitals (Beeler et al., 2013). The studies on pharmacists' information seeking are shown in Table 1C.

Table 1C *Studies on pharmacists' information seeking in pharmacies and specialized care, including the main information sources.*

Study name	**Authors (year, country)**	**Study results**	
		Main information sources	**Other results**
Pharmacies			
Pharmacist perception and use of UpToDate®	Wallace et al. (2014, UK)	online sources	majority of pharmacists adjust drug therapy based on UpToDate recommendations
Results of the Arizona Medicaid health information technology pharmacy focus groups	Warholak et al. (2011, USA)	electronic sources	pharmacists rank electronic prescribing the highest priority feature of electronic health system
The impact of pharmacy computerised clinical decision support on prescribing, clinical and patient outcomes: a systematic review of the literature	Robertson et al. (2010, Australia)	computer sources	good communication between physicians and pharmacists is needed to get benefits from a clinical decision support system in terms of drug safety issues
Specialized care			

Use of an on-demand drug-drug interaction checker by prescribers and consultants: a retrospective analysis in a Swiss teaching hospital	Beeler et al. (2013, Switzerland)	electronic sources	drug-to-drug interaction checker can be used between hospital physicians and pharmacists in patient care
Information-searching behaviors of main and allied health professionals: a nationwide survey in Taiwan	Weng et al. (2013, Taiwan)	online sources	pharmacists use specific online pharmaceutical sources

2.3 ONLINE SURVEILLANCE ON INFECTIOUS DISEASES

2.3.1 LYME BORRELIOSIS (LB)

LB is a bacterial infectious disease transmitted via ticks and mainly appears in northern temperate climate zones worldwide (Lindgren and Jaenson, 2006), including in Finland (located in Northern Europe). LB shows seasonal variation between the spring and autumn, with increased incidence in Europe (Lindgren and Jaenson, 2006; Bennet et al., 2006; Wilking and Stark, 2014; Nelson et al., 2015). The regional and temporal distribution of LB shows significant variation and increase in incidence in Finland (Sajanti et al., 2017). Lyme-disease–related online searches collected from Google Trends have been shown to approximate certain trends that are typical of the epidemiology of LB (Seifter et al., 2010). To forecast LB, a seasonal autoregressive moving average model (SARIMA) has been applied to compute register-data from the incidences of LB (Kapitány-Fövény et al., 2019). The studies on infectious diseases' surveillance online data are shown in Table 2.

2.3.2 INFLUENZA

Influenza occurs seasonally and follows temporal patterns during the colds months of the year. Influenza is a viral infectious disease spread via air or contaminated surfaces and it is mainly caused by two types of influenza viruses—A or B (Factsheet about seasonal influenza [ECDC]). Antiviral medications, such as oseltamivir, can be used to treat influenza. These neuraminidase inhibitors prevent the reproduction of the influenza virus. Oseltamivir can be used in adults or children and is available in either tablet or liquid form. The recommendation to start using oseltamivir includes being a patient with a high risk of complications (Dobson et al., 2015). Influenza epidemics can cause major public health concern worldwide, also in Finland. Oseltamivir has been classified on the list of essential medicines in the healthcare system (World Health Organization. Model List of Essential Medicines 20th List. March 2017).

Online surveillance systems have shown good congruence with traditional surveillance approaches (Milinovich et al., 2014). Google Flu Trends (GFT) includes query data from the online influenza-like illness searches. However, it has been stated that these GFT data should be incorporated in near real-time electronic health-data to improve detecting

influenza epidemics (Olson et al., 2013). Online health-information and epidemiological data could be combined (*infodemiology*) and used for surveillance purposes (*infoveillance*) (Eysenbach, 2009). Influenza query data from search engines and social media may enhance influenza surveillance (Santillana et al., 2015; Woo et al., 2016; Clemente et al., 2019). Many infectious diseases, such as LB, influenza, Zika, and dengue, have been studied by assessing online data, including general search engines and social media websites, to detect epidemics (Santillana et al., 2015; Majumder et al., 2016; Yang et al., 2017). Together with GFT, novel surveillance algorithms have also been developed in order to detect and predict influenza epidemics (Spreco et al., 2017; Spreco et al., 2018). The search data from Google Trends can be analyzed by using mathematical models called AutoRegression with Google search data (ARGO) and seasonal autoregressive moving average model (SARIMA) (Jung and Lee, 2016). The moving epidemic method (MEM) analyzes the timing of influenza epidemics by using the historical data on influenza rates on a weekly basis (Vega et al., 2013; Vega et al., 2015). The studies on infectious diseases' surveillance online data are shown in Table 2.

Table 2 *The online surveillance studies on Lyme borreliosis (LB) and influenza, as well as used mathematical models. MEM = the moving epidemic method, SARIMA = seasonal autoregressive moving average model, ARGO = AutoRegression with Google search data, GFT = Google Flu Trends.*

Study name	**Authors (year, country)**	**Study results**	
		Information sources	**Results**
The utility of "Google Trends" for epidemiological research: Lyme disease as an example	Seifter et al. (2010, USA)	Google Trends	Google Trends approximated the trends previously identified in the epidemiology of Lyme disease
Internet-based surveillance systems for monitoring emerging infectious diseases	Milinovich et al. (2014, Australia)	online sources	Internet surveillance systems have good congruence with traditional surveillance approaches, but they do not have the capacity to replace traditional surveillance systems
Reassessing Google Flu Trends data for detection of seasonal and pandemic influenza: a comparative epidemiological study at three geographic scales	Olson et al. (2013, USA)	GFT, emergency department visits	GFT should be incorporated in the use of near-real time electronic health data and computational methods
Combining search, social media, and traditional data sources to improve influenza surveillance	Santillana et al. (2015, USA)	Google, Twitter, hospital records	Combining information from multiple independent flu predictors is advantageous over simply choosing the best performing predictor
Studies on mathematical models used in infectious disease surveillance			
Study name	**Authors (year, country)**	**Study results**	
		Information sources	**Mathematical model**
Can Google Trends data improve forecasting of Lyme disease incidence?	Kapitány-Fövény et al.	Google Trends	SARIMA

	(2019, Hungary)		
Integrated detection and prediction of influenza activity for real-time surveillance: algorithm design	Spreco et al. (2017, Sweden)	local electronic health data repository	integrated influenza detection and prediction method
Comparison study of SARIMA and ARGO models for influenza epidemics prediction	Jung, Lee (2016, Korea)	officially-reported data from national institutions, Google search data	SARIMA, ARGO
Influenza surveillance in Europe: comparing intensity levels calculated using the moving epidemic method	Vega et al. (2015, several European countries)	EuroFlu database (WHO Regional Office for Europe)	MEM

2.4 SUMMARY OF THE LITERATURE

Information seeking behavior among physicians, nurses, and pharmacists varies. Diagnoses, medication, and treatment are the most queried topics from the sources. According to the literature review, it cannot be stated that the results and conclusions are similar between the studies in terms of information seeking among various HCPs, different healthcare sectors, or the types of information sources. There are discrepancies between the main information sources whether they are traditional (textbooks, colleagues) or electronic or online, indicating that even recent studies suggest the main source of information is colleagues, although online sources have increased over time. Unreliable information sources (Google) may provide heterogeneous health-related information. HCPs consider that the medical information found from electronic or online sources has an effect on decision-making and practice improving patient care. Google Trends on LB and influenza or other online sources could be used when detecting epidemics. The combination of various databases (traditional registers, online sources) could improve the detection of infectious diseases.

3 AIMS OF THE STUDY

This study aimed to assess HCPs' queries from online databases in order to detect infectious disease epidemics. The specific objectives were:

1. To analyze HCPs' needs for medical evidence in different healthcare sectors.
2. To describe HCPs' information seeking behavior and whether the queries could be used in disease surveillance.
3. To compare the queries between HCPs and the general public.
4. To describe how the general public queries information on a specific disease (Lyme disease) and whether media coverage has an effect on this seeking behavior.
5. To use a mathematical model (MEM) to analyze HCPs' queries and register-based data.

4 MATERIAL AND METHODS

4.1 DATABASES AND REGISTERS

4.1.1 PHYSICIAN'S DATABASES (PD)

The Finnish Medical Society Duodecim owns Duodecim Medical Publications Ltd that publishes medical information to HCPs. The chargeable online medical portal called Physician's Databases (PD) (Lääkärin tietokannat in Finnish) are targeted at HCPs who search for medical information in clinical work. The databases are available in the whole healthcare system in Finland. Different healthcare sectors (primary care, specialized care, pharmacies, and private care) and all twenty-one healthcare districts in Finland can be tracked using an Internet Protocol address. PD comprise point-of-care EBM Guidelines planned for clinical practice, including over 1,300 primary care practice guidelines with more than 4,000 evidence summaries abstracting the best research evidence for the corresponding diagnostic, treatment, or medication recommendations. The guidelines are also equipped with a link to Cochrane full-text reviews. Duodecim Medical Publications Ltd follows the process accredited by the National Institute for Health and Care Excellence (NICE) when producing the guidelines in the databases. PD also include National Current Care Guidelines published by Duodecim Medical Society. These guidelines provide an access to the Duodecim Medical Journal, Cochrane Library, Finnish Medical Journal, medication databases, acute care databases, and the search engine for ICD-10 (International Classification of Diseases, 10th Revision) and procedure codes. During the clinical encounter, a physician or other HCP (such as a nurse or pharmacist) may seek medical information by using a search word or opening a medical article included in the PD log file.

4.1.2 HEALTH LIBRARY (HL)

Duodecim Medical Publications Ltd produces and maintains the online health portal called the Health Library (HL) (Terveyskirjasto in Finnish) aimed at the general public. It is a free-of-charge online database comprising over 10,000 medical articles. In 2016, articles were opened over 50 million times. The medical articles in the HL are based on the guidelines in the PD. The logs of HL include only data on the entire country with no geographically distributional data. The contents of PD and HL are in Finnish.

4.1.3 HEALTHCARE PROFESSIONALS (HCPs) IN FINLAND

In 2016, the total number of working physicians in Finland (population of 5.5 million [Population Register Centre in Finland]) was over 20,000, consisting of 3,950 public primary-care physicians, 8,050 specialized-care physicians, and 5,500 private-care physicians. Most occupational-health physicians work in private care. The number of

private-care physicians also includes the physicians who work part time in the private sector, but are mainly occupied in the public sector. Nurses in public primary care and specialized care equal 18,591 and 33,940, respectively. The number of nurses includes only registered nurses, public health nurses, and midwives. Community pharmacists equal 4,496.

4.1.4 NATIONAL INFECTIOUS DISEASES REGISTER (NIDR)

The National Infectious Diseases Register (NIDR) is maintained by the National Institute for Health and Welfare (NIHW) (Infectious Diseases in Finland 2017). In Finland, microbiological laboratories notify the diagnostic findings electronically to NIDR, for example the laboratory reports of LB, and influenza A and B.

4.1.5 REGISTER OF PUBLIC PRIMARY HEALTHCARE DIAGNOSES (AVOHILMO)

NIHW maintains the database called the register of public primary healthcare diagnoses (Avohilmo) (Mölläri and Saukkonen, 2017). During a physician's encounter in the Finnish public primary healthcare, the diagnosis will be noted and then transferred to the Avohilmo database. The diagnoses are based on the ICD-10. Both databases, NIDR and Avohilmo, can be used in healthcare research, planning, and decision-making.

4.2 MEDIA WEBSITES

In Finland, the largest and most influential media companies are Yleisradio (Yle), Sanoma, and Alma Media. Sanoma comprises Helsingin Sanomat (the largest national subscription daily newspaper) and Ilta-Sanomat (a tabloid). Alma Media comprises MTV (a commercial television station) and Iltalehti (a tabloid). Yle is the national public broadcasting company in Finland. The number of five media website weekly browsers ranged between 1.6–2.8 million (December 2013) (TNS. Weekly statistics of the Finnish websites; Joukkoviestimet 2013: Finnish Mass Media). Along with these traditional platforms (the daily newspaper, tabloids, and television stations), they provide information on their websites. The website contains a search functionality that allows a consumer to search for information on the topics they desire.

4.3 DATA COLLECTION AND DESCRIPTIVE ANALYSES

Some words and terms used in the studies can be defined. In studies I and IV, *queries* refers to HCPs' openings of the medical articles in the PD. In study II, *searches* refers to HCPs' words they type in the search functionality of the PD platform. In study III, *openings* refers to medical articles that HCPs or the general public open in the databases. Due to the general public's queries on Lyme borreliosis (LB) from HL in study III, *Lyme disease* is used instead in referring to these queries performed by the public and to LB media publications. Otherwise, LB is used throughout the thesis. *Information seeking* (or *searching*) *behavior*

or *information retrieval* refers to an event where HCPs and/or the general public query information. *Queries/querying* and *searches/searching* refer to information seeking in general. *Internet* and *online* as well as *databases* and *sources* have similar meanings in the thesis.

In study I, the number of monthly queries from PD was collected in the following healthcare sectors nationwide during 2012–2018: primary care, specialized care, pharmacies, and private care. In addition, hourly queries in each sector were collected in the summer (July 4–10) and autumn (October 17–23) week in 2016. The Internet Protocol address differentiated the healthcare sectors. The study compared the medical queries by HCPs to the known (national statistics) opening hours, weekdays, weekends, seasons, and quantities of health personnel in healthcare sectors in Finland.

In study II, the search words *borre** or *lyme**, or *migrans** were collected from the PD and compared to the Avohilmo diagnoses of LB (A69.2, ICD-10) during 2011–2015. The number of search words and diagnoses were defined in the whole country and all twenty-one healthcare districts in Finland on a monthly basis. The Internet Protocol address located the healthcare districts in the PD. The three high-incidence LB regions in Finland (Helsinki and Uusimaa, Southwest Finland, and Kymenlaakso) were also analyzed. *Blood pressure* and *diabetes* served as comparison words to the LB search words.

In study III, the collection of Lyme disease articles from HL during 2011–2015 was carried out and categorized in weekly article openings in order to be comparable with the openings from PD. To collect the publications on Lyme disease, the search words *borrelioosi* and *punkki* (*borreliosis* and *tick* in Finnish) were typed in the webpages' search functionality of the five largest media websites. The articles found were categorized by the weekly publication date in order to be comparable to the article openings in the HL and PD. Only those publications released during Lyme disease off-season months (November, December, January) were chosen for further analysis.

In study IV, the influenza diagnoses (J09–11 [ICD-10] and R80 [International Classification of Primary Care, 2nd Edition (ICPC-2)]) were collected from the Avohilmo database and were compared to the log files of the queries on oseltamivir and influenza from PD and the laboratory reports of influenza A and influenza B found from NIDR during 2011–2016.

4.4 STATISTICAL ANALYSES

Study IV data concerning the starts and ends of the influenza seasons and thresholds (pre-epidemic, post-epidemic) were calculated by the MEM model using R language (version 2.12). Paired differences were used to analyze the starts of the influenza epidemics in terms of the queries on oseltamivir, influenza, influenza diagnoses, and laboratory reports of influenza A and B. Due to a small number of observations (starting weeks), the bootstrapping method computed the paired differences consisting of five indicators with 1,000 replications resulting in bootstrapped mean, bias-corrected, and accelerated (BCa) (adjusted for ties) 95% confidence interval (CI) of the mean, and p-value of the mean. Kendall's correlation coefficient (τ) assessed the statistical season-to-season similarity

between a pair. Paired differences and correlations were analyzed with SPSS software (IBM SPSS Statistics version 24). The data sources, data collection, and analyses of studies I–IV are shown in Table 3.

Table 3 *The data sources, data collection, and analyses of studies I–IV. PD = Physician's Databases, Avohilmo = the register of public primary healthcare diagnoses, HL = Health Library, NIDR = National Infectious Diseases Register, LB = Lyme borreliosis, ICD-10 = International Classification of Diseases (10th Revision), ICPC-2 = International Classification of Primary Care (2nd Edition), MEM = the moving epidemic method.*

	Data sources	**Data collection from sources**	**Years**	**Data analysis**
Study I	PD	PD: monthly and hourly queries in healthcare sectors (primary care, specialized care, pharmacies, and private care)	2012–2018	Descriptive: visual patterns of queries in healthcare sectors
Study II	PD Avohilmo	PD: monthly LB search words: *borre** or *lyme**, or *migrans** Avohilmo: monthly LB diagnoses (A69.2 [ICD-10])	2011–2015	Descriptive: visual patterns of LB search words and diagnoses
Study III	HL PD media websites	HL: weekly LB article openings PD: weekly LB article openings weekly media website LB publications (November, December, January), search words: *borrelioosi* and *punkki*	2011–2015	Descriptive: visual patterns of LB article openings and media publications
Study IV	PD Avohilmo NIDR	PD: weekly queries on oseltamivir and influenza Avohilmo: weekly influenza diagnoses (J09–11 [ICD-10] and R80 [ICPC-2]) NIDR: weekly influenza A and influenza B laboratory reports	2011–2016	Descriptive: visual patterns of queries, diagnoses, and laboratory reports Statistical: MEM model, paired differences (mean, confidence interval of the mean, p-value of the mean), Kendall's correlation

5 RESULTS

5.1 EVIDENCE NEEDS IN DIFFERENT HEALTHCARE SECTORS

The patterns of the HCPs' monthly medical queries from PD were visually distinct in different healthcare sectors in Finland. A number of queries remained stable during 2012–2018, even if the slight increase of queries could be seen in specialized and private care. The fluctuation of queries in primary care occurred stronger than in the other sectors. The summer troughs in private care and the occasional summer peaks in pharmacies appeared. The hourly queries in primary care occurred largest and mostly during opening hours of the healthcare centers (8 a.m.–4 p.m.). Queries in specialized care were performed in hospitals and emergencies during the daytime as well as throughout the night (9 p.m.–5 a.m.). Queries in pharmacies appeared in the evenings (after 4 p.m.) and on Saturdays. Queries in private care appeared to be fewer in summer than autumn. The double-peak patterns in all healthcare sectors occurred around noon, showing the morning and afternoon peak in hourly queries.

5.2 SIMILAR SEASONAL PATTERNS IN DATABASES AND REGISTERS

5.2.1 LYME BORRELIOSIS (LB)

The visually similar patterns in seasonal variation of LB appeared between the monthly searches from PD and diagnoses from Avohilmo nationwide (II, Figure 1). The three high-incidence regions of LB in Finland (Helsinki and Uusimaa, Southwest Finland, and Kymenlaakso) showed regional and seasonal variation in 2011–2015. The comparison words (*blood pressure* and *diabetes*) showed no temporal variation to the LB search words (*borre** or *lyme**, or *migrans**). Weekly article openings on Lyme disease from HL and PD in Finland during 2011–2015 coincided with each other (III, Figure 4). The searches (II) and openings (III) from these databases resembled the epidemiological data on LB found in Avohilmo and NIDR.

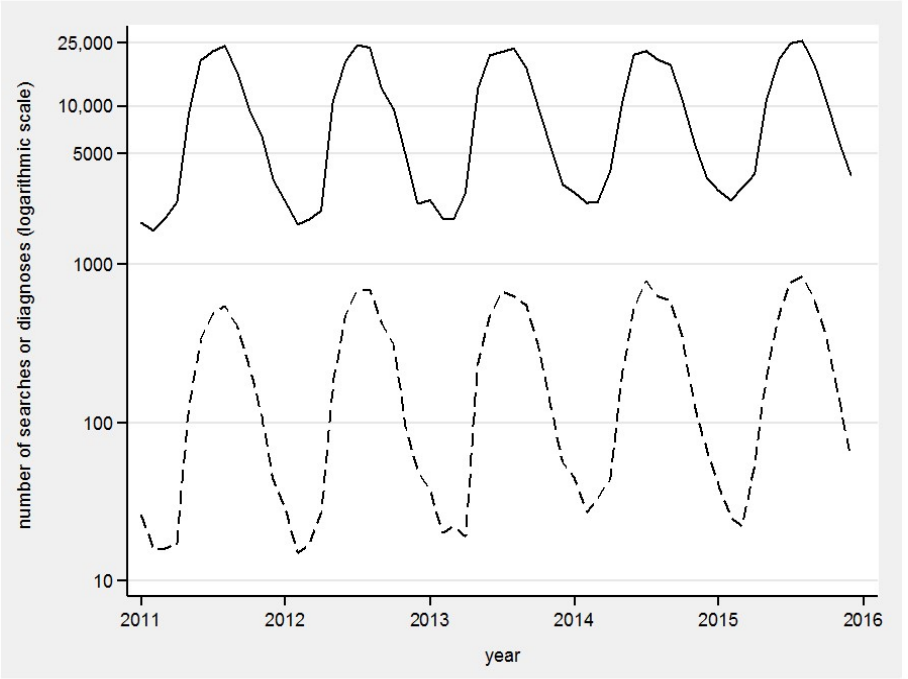

Figure 1 (Study II) Physician's Database searches for Lyme borreliosis (solid line) and Avohilmo diagnoses for Lyme borreliosis (dashed line) in the whole country during 2011–2015 (Pesälä et al., 2017)

5.2.2 INFLUENZA

The visually similar search patterns between the weekly queries on oseltamivir from PD and influenza diagnoses from Avohilmo occurred for five influenza seasons in Finland during 2011–2016. Similar patterns were found between the laboratory reports of influenza A and B and the queries on influenza (IV, Figure 2). The queries on influenza could be seen to precede other indicators (IV, Figure 2–3).

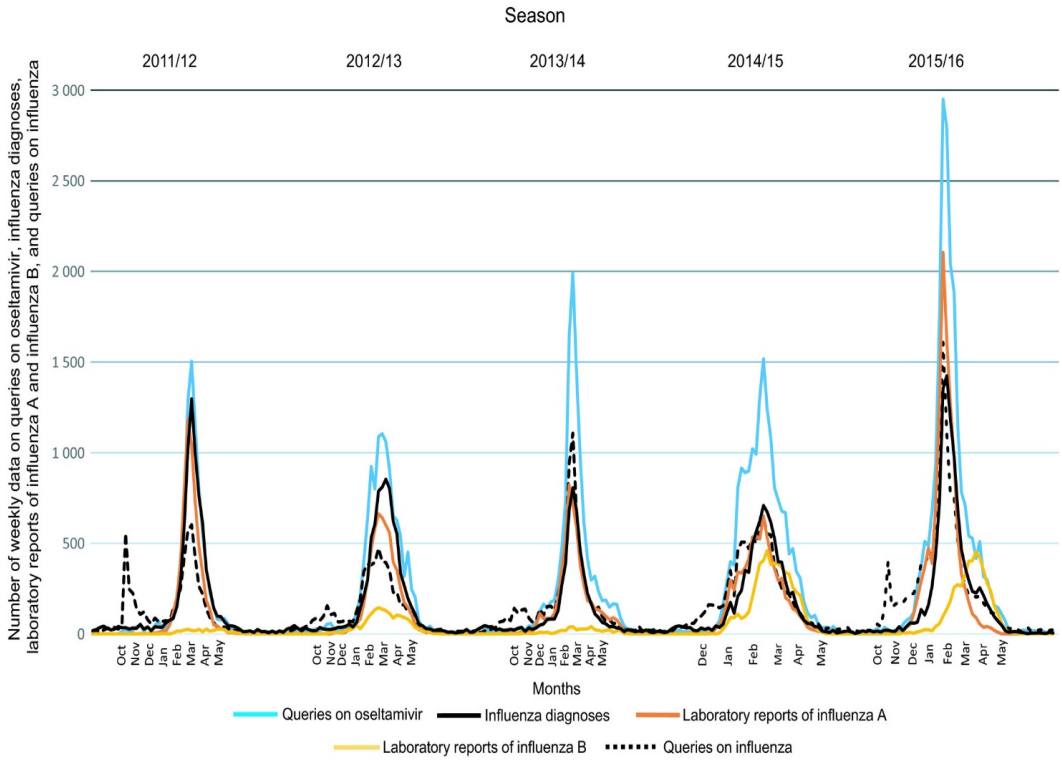

Figure 2 (Study IV) Queries on oseltamivir, influenza diagnoses, laboratory reports of influenza A and influenza B, and queries on influenza across Finland during 2011–2016 by season (Pesälä et al., 2019)

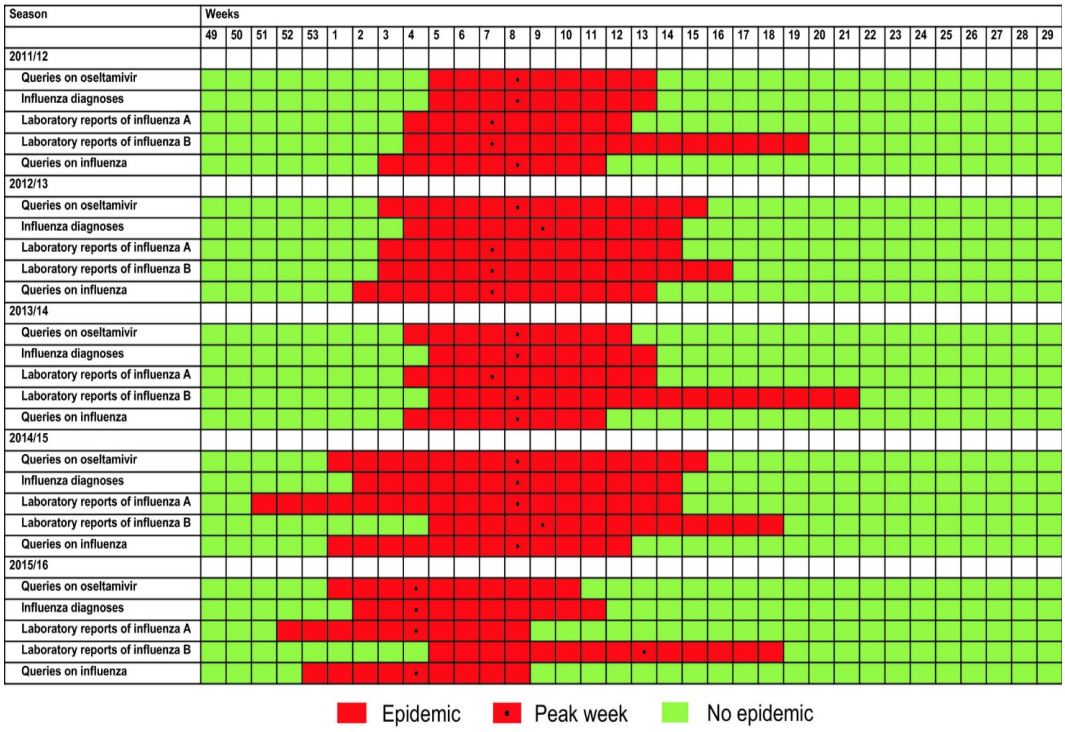

Figure 3 (Study IV) The MEM-calculated epidemic weeks (red) and non-epidemic weeks (green) on queries on oseltamivir, influenza diagnoses, laboratory reports of influenza A and influenza B, and queries on influenza by season. The black bullets indicate peak weeks during epidemic periods (Pesälä et al., 2019)

5.2.3 HEALTHCARE PROFESSIONALS (HCPs) VERSUS THE GENERAL PUBLIC

The seasonal variation of Lyme disease article openings between HCPs and the general public showed visually similar patterns from 2011 to 2015 (III, Figure 4). The article openings of the general public start at the beginning of May, peak between May and September, and decline to the lowest point between December and April. HCPs' article openings start at the end of April, peak between June and August, and decline to the lowest point between December and January. The openings have increased both at maximum (4.5-fold increase) and minimum (7.0-fold increase) among the general public, but the openings by HCPs have remained stable at maximum (1.1-fold increase). In addition, the greater fluctuations in the general public's opening patterns for Lyme disease articles appeared over time.

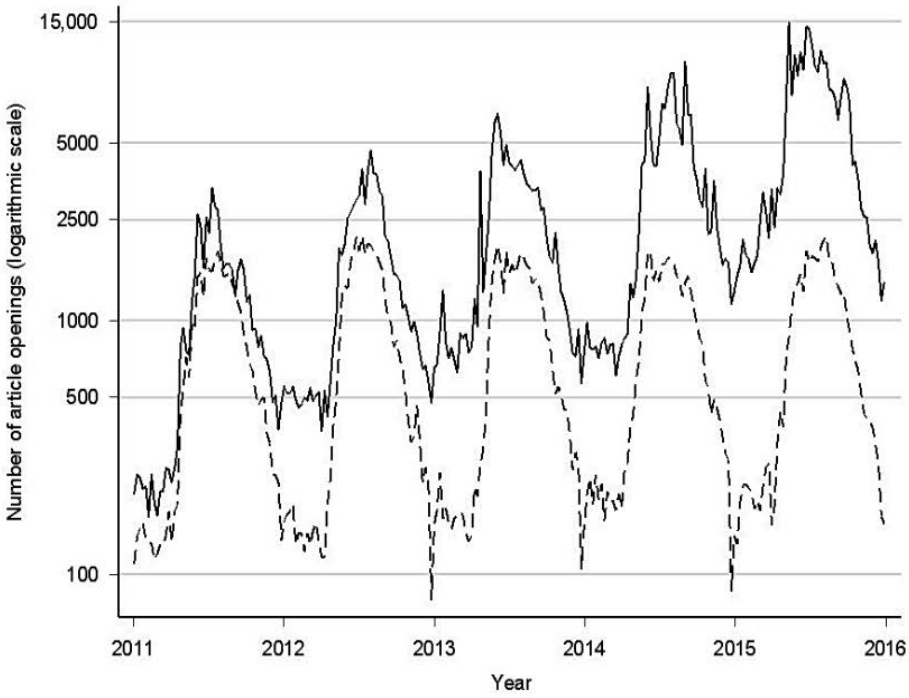

Figure 4 (Study III) The general public's article openings on Lyme disease in the Health Library (solid line) and healthcare professionals' (HCPs') article openings on Lyme disease in the Physician's Databases (dashed line) across Finland from 2011 to 2015 (Pesälä et al., 2017)

5.3 MEDIA PUBLICATIONS

A total of 25 media publications on Lyme disease were found from the largest media websites (Yleisradio, Helsingin Sanomat, Ilta-Sanomat, MTV, and Iltalehti) during the off-season months of Lyme disease (November, December, January). The publications comprised 21 text articles, 2 text articles with a notice of TV documentary, 1 notice of TV documentary, and 1 radio program. The division into the categories were carried out consisting of 15 institutional articles (i.e. university or research institution or a specialist's view), 7 personal stories (i.e. a person's experience on Lyme disease), and 1 publication including both the institutional view and personal story. Two publications comprised the journalist's reports on ticks or Lyme disease excluding institutional or personal views. Three peaks (January 2013, December 2013, and November 2014) in Lyme disease article openings from the databases occurred at the same time when the Lyme disease media publications were released.

5.4 START OF THE INFLUENZA SEASON

5.4.1 QUERIES ON OSELTAMIVIR AND INFLUENZA DIAGNOSES

The MEM-calculated weekly queries on oseltamivir started during weeks 1–5 and Avohilmo influenza diagnoses during weeks 2–5 (IV, Figure 3). Influenza epidemics based on the queries on oseltamivir preceded diagnoses by -0.80 weeks (95% CI: -1.0, 0.0, p = 0.000) with high correlation ($\tau = 0.943$).

5.4.2 QUERIES ON INFLUENZA AND OSELTAMIVIR, AND LABORATORY REPORTS OF INFLUENZA A AND INFLUENZA B

The queries on influenza came before the queries on oseltamivir by -0.80 weeks (95% CI: -1.2, 0.0, p = 0.015) with high correlation ($\tau = 0.738$) and influenza diagnoses by -1.60 weeks (95% CI: -1.8, -1.0, p = 0.000) with high correlation ($\tau = 0.894$). The queries on influenza preceded the laboratory reports of influenza A by -0.80 weeks (95% CI: -1.8, 0.4, p = 0.166) and influenza B by -2.40 weeks (95% CI: -3.8, -1.0, p = 0.002).

6 DISCUSSION

6.1 EVIDENCE NEEDS IN DIFFERENT HEALTHCARE SECTORS

6.1.1 PRIMARY CARE

Study I found that the queries from online medical databases could be used to assess HCPs' different needs for medical evidence in various healthcare sectors in Finland. Distinctions between the sectors could be found throughout the years 2012–2018. The higher number of queries with greater fluctuation in primary care comparing to other sectors could indicate that this sector's HCPs may face several patients from various specialties accessing the health service of the first-point-of-contact, as well as the diseases and needs for medical help may seasonally vary, thus causing the unsteadiness in HCPs' queries. The greater number of queries could indicate that patients in primary care are often unselected with undiagnosed symptoms, while specialized care receives patients that undergo preliminary examination and diagnosis in primary care. In addition, possible differences between the large number of Finnish healthcare centers may cause the fluctuation. Primary-care HCPs usually work in a more individual manner as well, thus increasing the queries from online databases. Although being used in various healthcare sectors in Finland, PD are firstly made for primary-care professionals comprising mainly general practitioners and nurses. The studies in the literature search (Ely et al., 1992; Einarson et al., 2004; Clarke et al., 2013) found that primary-care physicians' main information source was colleagues or paper sources, not electronic or online sources.

6.1.2 SPECIALIZED CARE

Literature shows that specialized-care physicians' lower usage of online sources might reflect preferences for other non-electronic sources of information (Cook et al., 2017). However, some studies suggest that HCPs in specialized care would use more online sources than other sources of information (Weng et al., 2013). Study I found that there are twice as many HCPs (physicians and nurses) working in specialized care than in primary care, even if the number of queries in specialized care is only a half that in primary care. HCPs in specialized care may have singular medical guidelines to follow and face-to-face consultations with colleagues are easier, thus decreasing the queries. This reflects HCPs' different working environments and information needs in these sectors showing typical features of Finnish healthcare (Health care in Finland. Ministry of Social Affairs and Health; The Finnish Health Care System. Sitra; Health care and social welfare personnel; Physicians in Finland. Finnish Medical Association; The Association of Finnish Pharmacies).

6.1.3 PHARMACIES

According to the literature search, pharmacists use electronic and online sources when finding information on medication (Warholak et al., 2011; Wallace et al., 2014). Study I could characterize the online queries in pharmacies. The summer peaks may indicate that pharmacy students start their supervised working period and seek more medical information from online sources, thus causing the peaks in queries. The number of HCPs working in pharmacies coincided with the queries appearing in this sector.

6.1.4 PRIVATE CARE

Few studies could be found on information seeking among HCPs working in the private healthcare sector (Singh, 2012; Argyri et al., 2014). Study I characterized the online queries in private care showing that a smaller number of queries occurred during the summer. This may indicate that fewer occupational healthcare physicians and more experienced professionals in this sector cause the decrease in queries. The number of HCPs working in private care coincided with the queries appearing in this sector.

Overall in study I, the time of day and week when the evidence was queried by HCPs clearly mirrored the typical features of each healthcare sector in terms of the opening hours, weekdays, weekends, summer and autumn weeks, and quantities of health personnel. This suggests that HCPs seek information from online sources in order to apply the best current medical knowledge in their clinical work.

6.2 DATABASE QUERIES AS AN ADDITIONAL SOURCE OF INFORMATION FOR DISEASE SURVEILLANCE

6.2.1 LYME BORRELIOSIS (LB)

Study II found that the LB searches from online databases and LB diagnoses from the register of public primary-care diagnoses coincided with each other annually and regionally in Finland and in the three high-incidence LB regions during 2011–2015. Study III found that the article openings by HCPs and the general public associated with each other and the known epidemiological data on LB. Thus overall, the HCPs' searches (II) and openings (III) on LB and the general public's openings (III) on Lyme disease could be used as an additional source of information for disease surveillance. Literature shows that Google Trends on Lyme disease online searches are typical of the epidemiology of LB (Seifter et al., 2010).

6.2.2 INFLUENZA

Study IV found that during the starting weeks of influenza epidemics in Finland 2011–2016, the queries on oseltamivir and influenza searched from online medical databases

statistically coincided with the register-based public primary-care diagnoses of influenza when using the MEM model. The queries on oseltamivir preceded influenza diagnoses, and the queries on influenza preceded queries on oseltamivir. To conclude the results of study IV, HCPs' queries on oseltamivir and influenza could be used as an additional source of information for disease surveillance when detecting influenza epidemics. Literature shows that online surveillance systems have shown good congruence with traditional surveillance approaches (Milinovich et al., 2014), but the GFT data should be incorporated in near real-time electronic health-data to improve influenza epidemic detection (Olson et al., 2013). Epidemiological data and Internet health-information could be combined (*infodemiology*) and used for surveillance purposes (*infoveillance*) (Eysenbach, 2009). The MEM model has been shown to assess the timing of influenza epidemics in European countries (Vega et al., 2013; Vega et al., 2015).

6.3 INFORMATION SEEKING BEHAVIOR AMONG HEALTHCARE PROFESSIONALS (HCPs)

Study I could characterize the detailed online evidence needs among physicians, nurses, and pharmacists working in the distinct sectors. Typical features of the different healthcare sectors and professionals' seeking behavior were observed. Literature shows that HCPs may have different evidence needs depending on the healthcare sector (Hider et al., 2009; Cook et al., 2017) and they prefer reliable medical information to make clinical decisions in daily work (Lialiou and Mantas, 2016; Mikalef et al., 2017; Stub et al., 2018). Online medical sources have increased over time (Einarson et al., 2004; Clarke et al., 2013; Weng et al., 2013), but the results from general search engines (Google) may be heterogeneous in medical quality (Purcell et al., 2002; Davies, 2011; Weng et al. 2013; Butler, 2013). Some HCPs may use Google Scholar when seeking health information online (Falagas et al., 2008). The literature search found that there are discrepancies in the main source of information suggesting that HCPs may use textbooks and colleagues over online sources, especially in primary care (Einarson et al., 2004; Clarke et al., 2013). Studies I–IV could show that HCPs in Finland use the dedicated Internet platform, PD, when seeking evidence in various healthcare sectors and during the epidemics of LB and influenza. The prior Finnish studies have found that medical students and younger physicians prefer medical information in Finnish and use online sources, such as PD, when searching for evidence (Renko et al., 2011; Renko et al., 2013; Renko et al., 2016).

Study IV found that HCPs' queries on oseltamivir and influenza associated with the register-based sources of influenza (primary-care diagnoses and laboratory reports of influenza A and B), thus suggesting that the searches could be used as a supplementary source of information for disease surveillance when detecting influenza epidemics. Many studies fail to characterize the user base of online platforms. However, one relevant study suggests that clinicians' influenza searches from the UpToDate database can be used as a digital surveillance tool in predicting influenza outbreaks (Santillana et al., 2014).

Media coverage (publications) on LB may affect HCPs' seeking behavior. Study II found that the double-peak patterns may possibly be related to media coverage. In addition, study III found that some Lyme disease media publications released coincided with the article openings by HCPs. The overall results of the media coverage indicate that HCPs may be affected by media publications resulting in the increased seeking behavior from the online databases. Literature has shown that health professionals' interests do not follow media coverage during infectious disease outbreaks (Kostkova et al., 2013).

6.4 INFORMATION SEEKING BEHAVIOR AMONG THE GENERAL PUBLIC AND MEDIA COVERAGE

When desiring to search for health-related information on the Internet, the general public usually starts searching from the general search engines (Fox and Duggan, 2015). Some may start from social networking websites, such as Twitter. The results from general search engines and social media sites may contain unreliable health information. Several factors, such as personal health disorders, thirst for knowledge, or media coverage, may affect users' searching behaviors (Eysenbach, 2006; Fox and Duggan, 2015). Study III found that not only did the general public's openings of Lyme disease from HL and HCPs' openings of LB from PD show similar temporal patterns, but stronger fluctuations among the general public also occurred. This suggests that media coverage may affect the general public's seeking behavior. The media publications on Lyme disease outside epidemic seasons were only occasionally associated with the openings, but the higher the media coverage by some publications, the higher the general public's access to HL. When merging the different types of Lyme disease publications (institutional texts and personal stories) together, a peak appeared, suggesting that single publications released in a short period of time may trigger the general public to search for online information on Lyme disease after having read these single publications and then access to HL. Since showing similar temporal patterns between the openings of Lyme disease articles and epidemiological data on LB, study III concluded that the article openings of the general public could be used as an additional source of information for disease surveillance.

A small number of studies have been published in terms of information seeking among the general public, including patients or their family members, concerning online health information seeking in general. However, several studies exist on specific diseases that represent information that is beneficial to the public and that are available from online sources (Impicciatore et al., 1997; Pérez-López and Pérez Roncero, 2006; Leithner et al., 2010). The findings from the relevant study are coherent with study III showing that public interest in searching for online information around major infection outbreaks associated with media coverage (Kostkova et al., 2013). In addition, social media platforms, such as Twitter, can be used by improving influenza surveillance and be combined with the GFT and traditional data sources (Santillana et al., 2015).

Together with HCPs seeking medical information, the general public also shows interest in current health issues, especially when published on Internet platforms. Lyme disease appears seasonally (II) and triggers interest among the public in geographically endemic areas. Regarding Lyme disease article openings and media publications released (III), the seasonal associations occurred between the log data and registers. Given that Internet access broadened and platforms increased over time, the general public may now be connected and interacting with each other online, making them an important part of the novel surveillance systems, such as general search engines and social media websites. However, media coverage during the current disease outbreaks may raise concerns among the public as well as the professionals, thus possibly increasing the searches in the databases. Early warning systems may monitor the searches from a true epidemic, as well as an epidemic of fear, so-called *fear epidemiology* (Eysenbach, 2006). During disease outbreaks, the positive feedback loop may occur between the online searches and published media reports by triggering readers to search for information resulting in more disease-related information on Internet platforms. This makes readers face more disease information and then carry out more searches. Mass media highlights current breaking issues on several online platforms, accelerating the loop itself even more. These phenomena of *fear epidemiology* and the positive feedback loop can occasionally be seen in the case of Lyme disease in study III. When worrying about the symptoms of Lyme disease during epidemics, the general public may seek medical help from the units of healthcare sectors, especially primary and private care, thus increasing the HCPs' queries in these sectors.

6.5 STRENGTHS AND LIMITATIONS OF THE STUDIES

The strengths of the studies (I, II, III, IV) were timeliness and representativeness showing that the queries from real-time online medical sources (PD) aimed at HCPs could be assessed. The Internet Protocol address located the queries in different healthcare districts and sectors in Finland. The national epidemiological registers (Avohilmo, NIDR) on infectious diseases (LB and influenza) served as comparison material to the queries. Temporal patterns in queries, diagnoses, and laboratory reports could be found.

These studies include certain limitations. In study I, some queries in the log files could not be linked to any healthcare sectors distinctively according to the Internet Protocol address. These queries were omitted. A very small number of queries in some sectors were also excluded from the study. These sectors comprised HCPs with no information on the number of HCPs working in the non-clinical healthcare sectors.

The register of public primary-care diagnoses and log files of PD and HL are all different databases that could not be linked with each other. The visual patterns shown in the results of the studies may vary due to the different qualities of the databases (II, III, IV). Since a physician searches for information and makes a note for a diagnosis, these searches and diagnoses could not be traced to the same patient (II, IV). Along with the general public searching for information from HL, some HCPs may also access HL. In addition, the

searches performed by various HCPs, including physicians (general practitioners, specialists), nurses, and pharmacists, are indistinguishable from each other (I).

In study III, HL includes only openings of Lyme disease articles with no opening data on geographical distributions. The general public accessing HL, possibly via Google, may be more health conscious and capable of filtering health information. The article openings could not be associated with every media publication on Lyme disease due to the smaller media coverage during off-season months. In collecting Lyme-disease–related publications from the largest media websites, some publications on less frequented websites may also exist.

In study IV, the queries on oseltamivir from PD appeared larger than influenza diagnoses from the primary-care register. This may be due to the presence of some secondary-care queries on oseltamivir and absence of some diagnoses of influenza reported as being in a broader category of infectious diseases. Among healthcare centers, there may be a wide variation of noting the diagnoses in the primary-care register. The larger queries on oseltamivir among HCPs may indicate that media coverage or patients' worries about influenza prior to or during epidemics may increase the queries in the databases. In addition, oseltamivir is quite a rare medication to prescribe outside influenza epidemics, thus increasing the number of queries. The double-peak patterns occurred in the influenza queries consisting of the first and second peak (IV, Figure 2). The first one is smaller, appearing at the beginning of yearly influenza vaccinations; while the second is larger, appearing in the peak week of an epidemic. The first peak may indicate that HCPs search for information on influenza vaccines included in the influenza article in the PD. The first peak was excluded from the MEM analysis, even if the queries on influenza could be seen to proceed other indicators (IV, Figure 2). This may slightly bias the results.

All the studies, I–IV, comprised the log data from PD, thus showing the typical characteristics of the databases that collected the queries by the users. Many phenomena may influence users' seeking behavior, including medical and non-medical issues they face daily in a professional environment and beyond. This interaction could result in the visual patterns of queries with unexpected peaks and troughs. Some of these may be associated with current infectious diseases or media coverage from health issues even if the most may remain unexplained. It is impossible to filter some data on non-epidemiologic backgrounds gathered in the databases, especially when coming from the general search engines or social media websites used by the general public during disease outbreaks (*fear epidemiology)*. In addition, online databases are regularly updated, and new functions are included onto platforms. Therefore, the peaks and troughs can be found in the patterns when occasional overlapping in queries might sometimes occur.

7 CONCLUSIONS

This study aimed to assess HCPs' queries from online databases in order to detect infectious disease epidemics. The specific objectives were fulfilled:

1. The needs for medical evidence among HCPs in different healthcare sectors could be analyzed and were found to coincide with the sector characteristics.
2. HCPs' information seeking behavior could be described. The results found that the queries could be used as a supplementary source of information for disease surveillance.
3. The queries between HCPs and the general public could be compared and were found to coincide with each other.
4. The queries on a specific disease (Lyme disease) among the general public could be described. Media coverage may have some effect on seeking behavior among the general public.
5. Using a mathematical model (MEM) to analyze HCPs' queries and register-based data on influenza showed that online queries preceded epidemiological data.

8 SUMMARY

HCPs prefer medical information based on best clinical practice that can be used in daily patient work (Lialiou and Mantas, 2016; Mikalef et al., 2017; Stub et al., 2018). Electronic and online sources of information have increased in comparison with colleagues and textbooks (Einarson et al., 2004; Clarke et al., 2013; Weng et al., 2013). Different working environments and lack of time during patient encounters, as well as heterogeneous health information available in the databases, may limit information retrieval among HCPs. This may result in poorer quality in decision-making and patient care (Diaz et al., 2002; Eysenbach et al., 2002; Fahy et al., 2014). The personal features and knowledge, such as searching skills, attitudes towards new information technology systems, hesitation to consult senior colleagues, and information interpretation skills, may have an individual effect on a professional's seeking behavior (Dawes and Sampson, 2003). Notably, media coverage on current health issues published on several Internet platforms may influence HCPs, thus change their information retrieval from sources (Kostkova et al., 2013; Butler, 2013). General search engines and social media websites may still remain a barrier for HCPs to seek reliable real-time medical information online (Purcell et al., 2002; Davies, 2011; Weng et al. 2013; Butler, 2013).

Various HCPs may present different needs for medical information depending on the healthcare sector they work in (Hider et al., 2009; Cook et al., 2017), including the features of each sector with specific opening hours, time of day, day of week, seasons, and the number of various HCPs working in sectors. Since the characteristics and personnel are known in the Finnish healthcare sectors, studies need to be performed to strengthen the hypothesized knowledge on HCPs' information seeking from online databases.

The traditional register-data in infectious disease surveillance have widely been used when detecting disease outbreaks, such as using primary-care diagnoses and laboratory positive findings in predicting seasonal influenza (Cooper et al., 2009; World Health Organization. Global Epidemiological Surveillance Standards for Influenza). Accessing the Internet and its logs has broadened traditional surveillance into real-time methods to detect epidemics, such as using the log files of general search engines and social media websites (Santillana et al., 2015; Majumder et al., 2016; Yang et al., 2017). The search trends from Google have been used to estimate the activity of infectious diseases, such as GFT in influenza activity (Olson et al., 2013) and Google Trends in forecasting LB (Seifter et al., 2010). Epidemiological data and online health-information could be combined (*infodemiology*) and used for surveillance purposes (*infoveillance*) (Eysenbach, 2009). Even if the results from the studies have provided novel findings to be used in infectious disease surveillance, many still lack the platforms for the definite users, such as HCPs. This uncertainty, of heterogeneous user base, limits those studies to benefit the online log data to detect epidemics. Therefore, further research is needed to study the databases characterized by specific users as well as to define the various healthcare sectors where the information is searched for.

Physician's Databases (PD) serve as online medical sources that are available throughout the Finnish healthcare system and provide reliable information for HCPs. Several HCPs in various healthcare sectors use PD in daily work when needing medical evidence in clinical practice. Every search word they type and every medical article they open are collected in the log files of PD according to the Internet Protocol address. The aim of this study was to analyze information seeking among HCPs from the dedicated online medical databases to compare the queries with register-based data on infectious diseases (LB and influenza) and to assess if the queries could be used as an additional source of information for disease surveillance when detecting epidemics. According to epidemiological registers, LB and influenza show the annual and seasonal patterns of diagnoses collected from public primary-care encounters: LB in the summer and influenza in the winter. Therefore, these two infectious diseases were chosen as case studies to be analyzed in their distinct seasonal variations, and the comparisons with PD log data could be made. The material and methods of the study included the descriptive and statistical analyses of the queries from the log files of PD and the diagnoses and laboratory reports from epidemiological registers. Lyme-disease–related publications from the media websites were also assessed.

To analyze the needs for evidence among various HCPs, the queries in different healthcare sectors (primary care, specialized care, pharmacies, and private care) showed the typical features of each sector in terms of the time of day, weekdays, weekends, seasons, and quantities of HCPs working in a specific healthcare sector nationwide (I). To detect infectious disease epidemics, similar patterns were found between the diagnoses and queries of LB performed by both HCPs and the general public (II, III). The media publications on Lyme disease related to queries only occasionally (III). However, this indicates that media coverage on Lyme disease may have an influence on both HCPs and the general public when searching for health information online. HCPs' queries on oseltamivir and influenza showed similar patterns annually comparing with the diagnoses and laboratory reports of influenza (IV). When detecting influenza epidemics, the queries on oseltamivir preceded influenza diagnoses, and the queries on influenza preceded oseltamivir queries and influenza diagnoses, when using the MEM model and paired differences of the mean (IV). To assess the log files of PD and to compare them with epidemiological registers on infectious diseases, heralds a new approach for using HCPs' online queries from real-time databases as an additional source of information for disease surveillance when detecting epidemics.

9 FUTURE PROSPECTS

To detect infectious disease epidemics, traditional surveillance methods have included the collection of diagnoses from physicians' encounters or positive findings (laboratory reports) at microbiological laboratories. The development of electronic patient record systems, together with access to online sources and other computer systems, has facilitated the development of new platforms consisting of enormous amounts of data with patients' details coming from HCPs' notes, laboratories' findings, and also from health information that patients report themselves. Since having different systems, including the online query data from HCPs and traditional register-based data, these two surveillance platforms could be combined in order to enhance current surveillance systems. The emerging possibilities for healthcare technology, including tools for artificial intelligence and machine learning (Haverinen et al., 2019), may enable healthcare units to become prepared for upcoming epidemics. In the future, algorithms could be created to analyze HCPs' queries in real-time from different healthcare sectors nationwide. To detect the start of an epidemic, information from these sources (diagnoses and laboratory data versus HCPs' online query data) could be combined, including the data from general search engines, social media, and media coverage on the Internet. In addition to HCPs' queries, the general public's information seeking on infectious diseases from various online platforms could be benefitted. The data from several sources may be delivered to healthcare units facing the first patients at the beginning of an epidemic to assess the needs for increased healthcare services and workforce.

Future research should focus on validating the material and methods used in studies I–IV by assessing HCPs' information seeking on the queries on oseltamivir and influenza in each healthcare district in Finland. Further studies on LB could supplement the knowledge on epidemiological and log data in order to assess the increase in LB incidences and new geographical areas where LB might have extended in Finland (Sajanti et al., 2017). Along with the MEM model, other mathematical models, such as ARGO and SARIMA, could be applied to PD log data. Further studies will analyze how various HCPs in different healthcare sectors search for information on liquid oseltamivir for children and does this seeking behavior mirror the features of HCPs working in each healthcare sector. In the future, HCPs' queries on various cough and antibiotic mixtures prescribed for children will be studied and compared to medical guidelines to avoid cough medicine and antibiotics for children in certain circumstances, so-called *Choosing Wisely Recommendations*, in order to assess if HCPs' queries from online databases have decreased after publishing the guidelines on PD platforms. The incidences and log data on other infectious diseases, such as respiratory syncytial virus (RSV) in small children and norovirus outbreaks, could be applied to detect epidemics. Showing differences in the timing of seasons (Renko and Tapiainen, 2019), the online RSV log data could be used to supplement epidemiological data when predicting RSV epidemics in small children.

When analyzing the log data of HCPs' medical information seeking from online databases, new knowledge on information needs among HCPs could be characterized. Once identified and assessed as well as probable improvements recognized, intervention methods

could be focused on HCPs' and students' searching skills regarding part of continuous professional learning and medical education (Renko et al., 2011; Renko et al., 2013). This may include additional courses or guidelines provided for HCPs and students. Characterizing the information needs of HCPs, will aid in the development of online databases and computer systems.

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